The Rotator Cable: Magnetic Resonance Evaluation and Clinical Correlation

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KEYWORDS

• Rotator cable • Rotator cuff • MR imaging • Shoulder injury

The rotator cable was first described in a study by Clark and Harryman[1] as a fibrous band coursing along the undersurface of the supraspinatus and infraspinatus tendons perpendicular to their fibers and continuous with the coracohumeral ligament anteriorly. Burkhart and colleagues[2,3] confirmed the presence of this structure and named it the cable, a descriptive term related to its biomechanical role in these investigators' model of rotator cuff function and failure. The rotator cuff tendon fibers extending distal to the lateral margin of the cable to the greater tuberosity attachment were named the crescent (**Fig. 1**).[2–5]

Based on Burkhart's biomechanical studies,[3,4] 2 different types of functioning rotator cuff tendons have been described: cable-dominant and crescent-dominant. The cable-dominant rotator cuff was theorized to occur in older persons whose cable absorbs the stress produced by the supraspinatus and infraspinatus tendons while shielding the crescent fibers. The crescent would undergo atrophy and thinning related to the shielding, while assuming a markedly reduced role in the biomechanical function of the rotator cuff. Alternatively, the cable would undergo hypertrophy as it assumed the major role in biomechanical functioning. A crescent-dominant rotator cuff was theorized to occur in younger patients. In this scenario, there was no stress shielding of the crescent by the cable and no associated cable hypertrophy.[3,4] Thus, the cable would not play a major role in the biomechanical function of the rotator cuff.

The rotator cable also plays an important part in Burkhart's model of a rotator cuff tear, in which it functions as the loaded cable of a suspension bridge (**Fig. 2**). In this model, the cable absorbs the compressive and tensile stress produced by the supraspinatus and infraspinatus tendons. The compressive stress is transmitted to its anterior and posterior osseous insertions that serve as the supporting towers where the stress is dissipated. The tensile stress is absorbed and dissipated by the cable itself. According to this model, stress is transferred from the cuff muscles to the rotator cable as a distributed load, thereby stress-shielding the thinner, avascular crescent tissue, particularly in older persons.[2,5] The cable and its osseous insertions also serve as medial to lateral and anterior to posterior barriers in this model, limiting the propagation of tears involving the crescent while preserving the rotator cuff function.[2–5]

ANATOMY

Gross/Histology

There have been several studies describing the gross and magnetic resonance (MR) anatomy of the rotator cable.[6–10] Gross studies have shown a close anatomic relationship between the rotator cable and the coracohumeral ligament.[1,6,7] The

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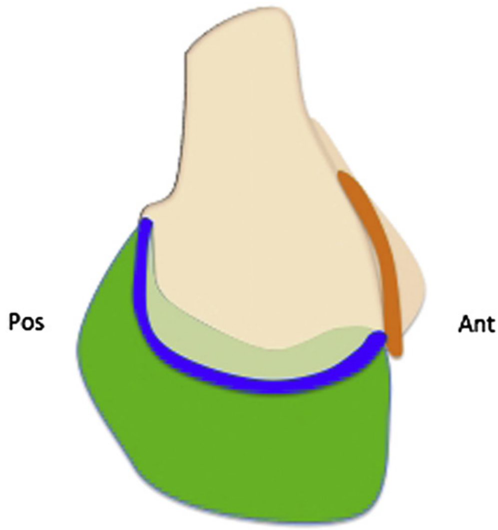

Fig. 1. Rotator cable. The rotator cable is shown as a blue curvilinear band coursing along the supraspinatus and infraspinatus tendons (*green*). The anterior insertion is at the anterior margin of the supraspinatus tendon adjacent to the biceps tendon (*orange*) and the posterior insertion is found along the posterior margin of the infraspinatus tendon. The crescent fibers (*light green*) extend from the margin of the cable to their insertion onto the greater tuberosity.

coracohumeral ligament arises from the rotator interval and envelops the rotator cuff with superficial and deep limbs (Fig. 3). The superficial limb is diminutive and lies along the bursal surface of the tendons. The deep limb is thought to represent the cable and tends to be a larger, thicker structure. The anterior insertion site of the cable is found at the greater tuberosity along the anterior margin of the supraspinatus tendon, just posterior to the biceps tendon. The cable then extends posteriorly perpendicular to the long axis of the supraspinatus and infraspinatus tendon fibers, interposed between the rotator cuff undersurface and the joint capsule. The posterior margin of the cable inserts along the inferior border of the infraspinatus tendon. The cable forms the medial margin of a crescent-shaped area that includes the distal fibers of the supraspinatus and infraspinatus, known as the crescent, located approximately 1.1 to 1.5 cm from the greater tuberosity.[3,6] Studies have shown variable degrees of thickness and width of the cable ranging between 1.2 to 4.7 mm and 4.5 to 12.1 mm, respectively.[3,6] The crescent includes the critical zone, a hypovascular region of the rotator cuff that tends to undergo attritional change and degenerative tearing over time.[11–13] Histologic examination has demonstrated the cable as a fibrillar

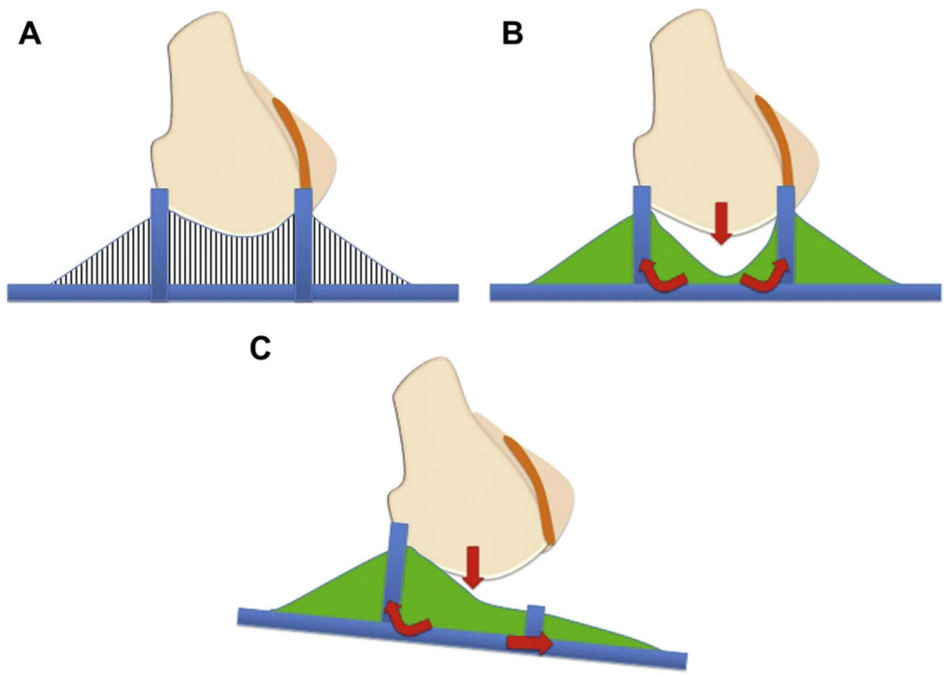

Fig. 2. (*A*–*C*) Biomechanical suspension-bridge model for a rotator cuff tear. (*A*) The anterior and posterior attachments of a tear correspond to the anterior and posterior supports at either end of the cable, and the free edge of the tear corresponds to the cable. (*B*) As long as the cable's insertions are intact, cuff fibers can continue to act as a compressor of the humeral head because the load is distributed along the cable to its insertions (*red arrows*). (*C*) If the tear extends to and involves one of the insertions, the cuff loses its compressive ability and becomes biomechanically unstable.

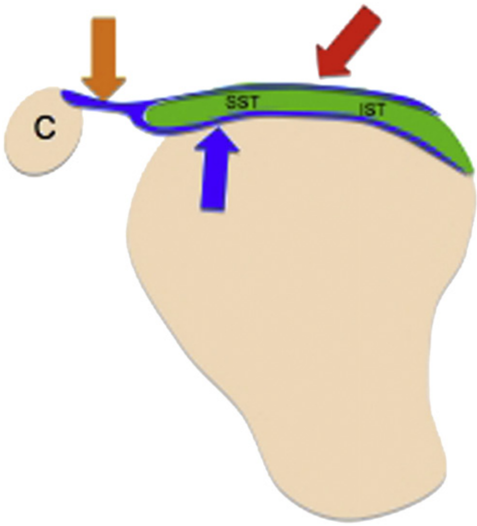

Fig. 3. Coracohumeral ligament extensions. The coracohumeral ligament (*orange arrow*) has 2 extensions that course along the bursal and articular surfaces of the supraspinatus (SST) and infraspinatus (IST) tendons; and a smaller superficial limb (*red arrow*) and a larger, deeper limb that correspond to the rotator cable (*blue arrow*). C, coracoid process.

collagenous structure separate from the supraspinatus and infraspinatus tendon fibers.[6,7]

Imaging

Several studies have examined the imaging appearance of the rotator cuff cable.[6,8,9] The rotator cuff cable is consistently seen on an ultrasonogram as a fibrillar structure coursing perpendicular to the supraspinatus and infraspinatus tendons.[6] The rotator cuff cable can be seen in all the main imaging planes used in MR imaging. In both the coronal oblique and the abducted, externally rotated (ABER) planes, the rotator cable appears as a region of hypointense signal intensity along the undersurface of the supraspinatus and infraspinatus tendons that is continuous with the coracohumeral ligament (**Fig. 4**). The oblique coronal plane provides a cross-sectional view of the rotator cable, and therefore is most useful in the assessment of its craniocaudal thickness and width. In this plane, the cable is typically seen as a rounded focus of hypointense signal on all pulse sequences varying in craniocaudal size from 1 to 5 mm (**Figs. 5** and **6**A). In some instances, however, the cable appears as a broad, dotted line (see **Fig. 6**B). In the authors' experience, a prominent cable is more often visualized among individuals in the fifth to seventh decades of life, who undergo MR imaging of the shoulder in a search for rotator cuff disease. In these cases, the presence of an undersurface fraying and a shallow tearing of the rotator cuff may help highlight the margins of the cable, increasing its conspicuity. Differentiating the rotator cable from the retracted lateral edge of an articular surface partial tear of the supraspinatus tendon can be challenging, and the authors find triangulating the suspected cable in the axial plane most useful. A true cable will be seen extending from its anterior attachment in the greater tuberosity to its posterior oblique facet insertion in the axial images as opposed to the more focal changes seen in a retracted tear of the supraspinatus articular surface. In young adults, the cable may not be as easily discriminated from the adjacent rotator cuff tendon fibers. Inconsistent visualization of the cable in the setting of partial and full-thickness tears of the rotator cuff has been reported.[9]

Kask and colleagues[8] demonstrated consistent MR imaging visualization of all or parts of the cable in cadaver specimens, with the axial plane providing the most information. In particular, the middle portion of the cable, defined as the segment along the undersurface of the supraspinatus tendon, was seen best in the axial plane. In the axial plane, the body of the cable is seen as a linear or slightly curvilinear region of hypointense signal located approximately 1 to 1.5 cm medial to the outer cortical margin of the greater tuberosity (**Fig. 7**A). Care should be taken to assess for the presence of the cable at the level of the supraspinatus anterior and posterior intramuscular tendons, because the coracoacromial ligament can sometimes be seen coursing over the rotator cuff with the same orientation in consecutive higher axial sections. In the authors' experience, confirmation of the presence of the rotator cable in the oblique coronal plane by triangulation with the axial images is of great clinical utility.

In the sagittal plane, the cable appears as a continuous longitudinal band of hypointense signal oriented in the anteroposterior direction of variable thickness along the articular margin of the supraspinatus and infraspinatus tendons (see **Fig. 7**B). In this plane, the cable is continuous with the coracohumeral ligament anteriorly.

In the ABER plane, the coracohumeral ligament component of the biceps pulley must be identified at the level of the rotator interval and proximal margin of the bicipital groove (**Fig. 8**A). The cable can then be tracked from this point along the undersurface of the rotator cuff tendons, supraspinatus anteriorly and infraspinatus posteriorly, respectively (see **Fig. 8**B–F). Sheah and colleagues[9] visualized the cable as a minimal thickening of the undersurface of the supraspinatus tendon located approximately 1.1 to 1.5 cm medial from the greater tuberosity. These investigators

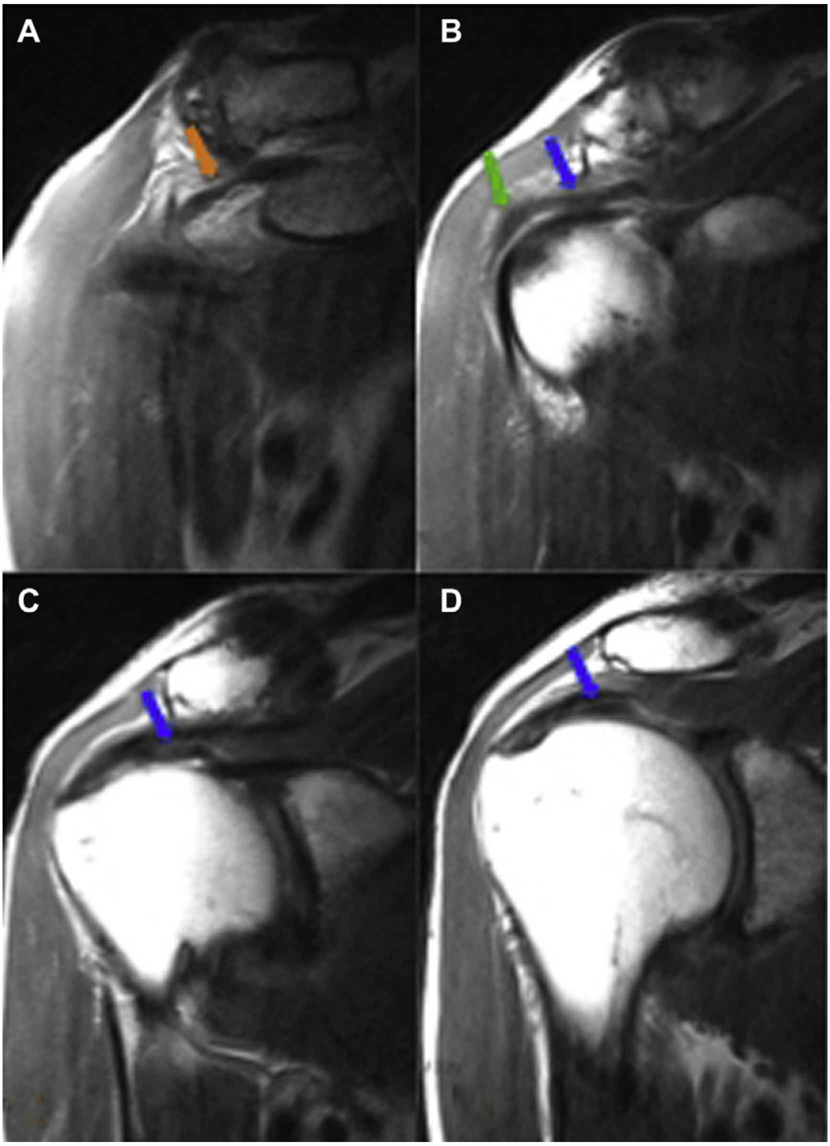

Fig. 4. (*A–D*) Rotator cable in the oblique coronal plane (proton-density weighted image). (*A*) The coracohumeral (CH) ligament originates from the coracoid process (*orange arrow*). (*B*) As it courses posteriorly, the CH ligament gives off the rotator cable (*blue arrow*), which blends and inserts anteriorly with the anterior margin of the supraspinatus tendon adjacent to the long head of biceps tendon (*green arrow*). (*C*, *D*) The rotator cable continues its course posteriorly along the undersurface of the supraspinatus and infraspinatus tendons (*blue arrows*).

most consistently visualized the cable in the ABER position in both the intact and torn rotator cuff (see **Fig. 8**; **Fig. 9**). In Sheah's series, the cable was not identified on the non-ABER MR arthrographic images of persons with intact rotator cuffs. In the authors' experience, however, the edges and insertions of the cable can be estimated in 1 or more of the imaging planes in a large proportion of individuals with and without rotator cuff tears who undergo MR imaging evaluation of the shoulder.

PATHOLOGY

MR imaging has been proven to be a reliable and accurate imaging method in the diagnosis and characterization of rotator cuff tears.[14–17] Its role in the evaluation of the rotator cuff cable is not as well defined. Most literature describes the use of the rotator cable and its modifications as a secondary sign of rotator cuff tearing more than as a primary site of pathologic condition.

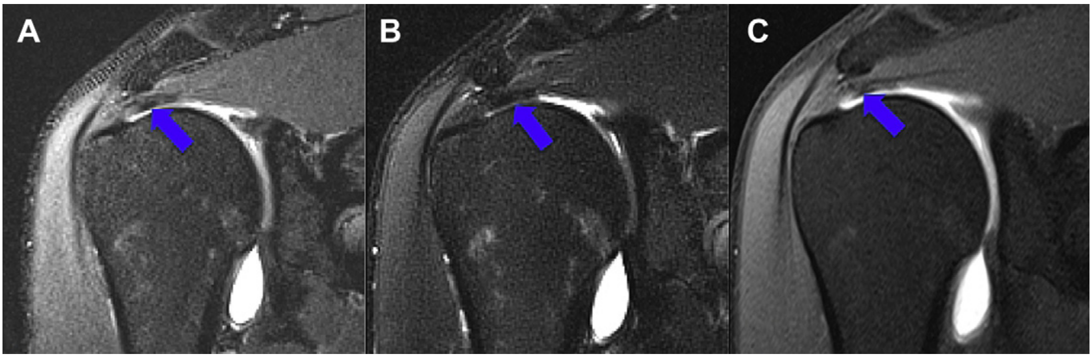

Fig. 5. Rotator cable on different pulse sequences. The rotator cable is demonstrated as a focal region of hypointense signal along the undersurface of the supraspinatus tendon (*blue arrow*) on the proton-density (*A*; repetition time [TR] 1000, echo time [TE] 50), fat-suppressed T2 (*B*; TR 3800, TE 79), and fat-suppressed T1 arthrogram (*C*; TR 446, TE 8.6) coronal oblique images in the same patient.

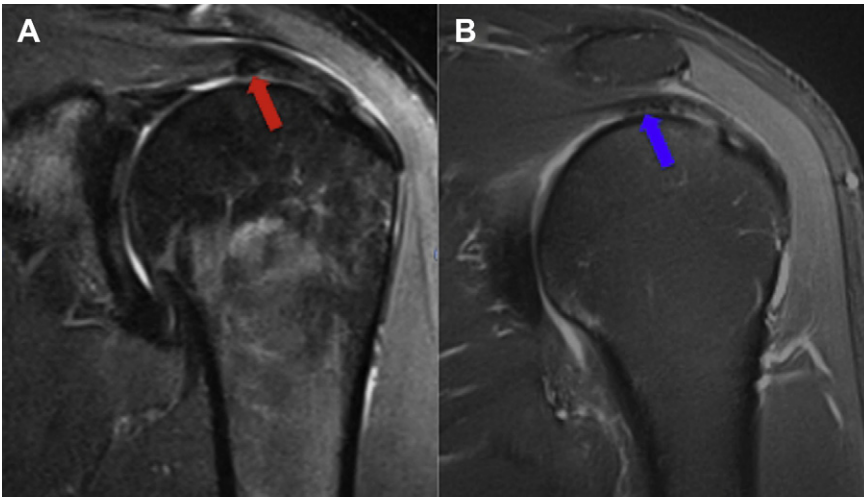

Fig. 6. Variations in width and thickness of rotator cable. Coronal oblique fat-suppressed proton-density (*A*) and T2-weighted (*B*) images in 2 different patients demonstrate a narrow thick cable (*red arrow* in *A*) and thin, broad rotator cable (*blue arrow* in *B*).

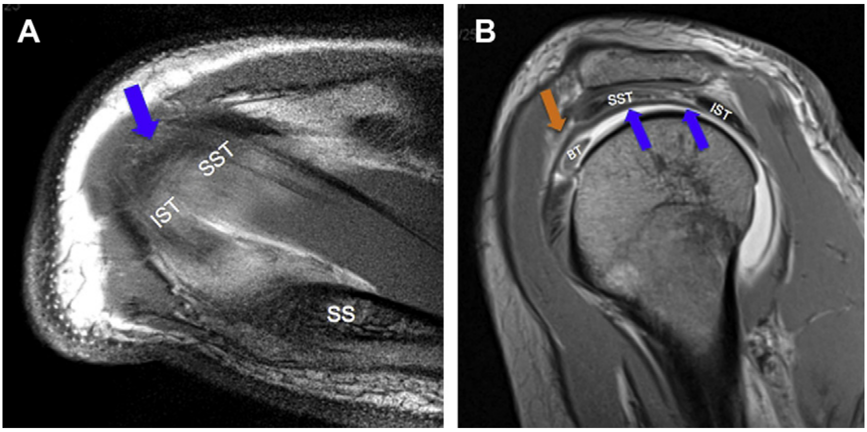

Fig. 7. (*A*, *B*) Rotator cuff cable in a cadaveric specimen. (*A*) The rotator cable is seen as a curvilinear band of hypointense signal intensity along the undersurface of the supraspinatus (SST) and infraspinatus (IST) tendons (*blue arrow*). (*B*) The rotator cable (*blue arrows*) extends from the coracohumeral ligament (*orange arrow*) and courses along the undersurface of the supraspinatus (SST) and infraspinatus (IST) tendons in this sagittal T1-weighted image. BT, biceps tendon; SS, scapular spine.

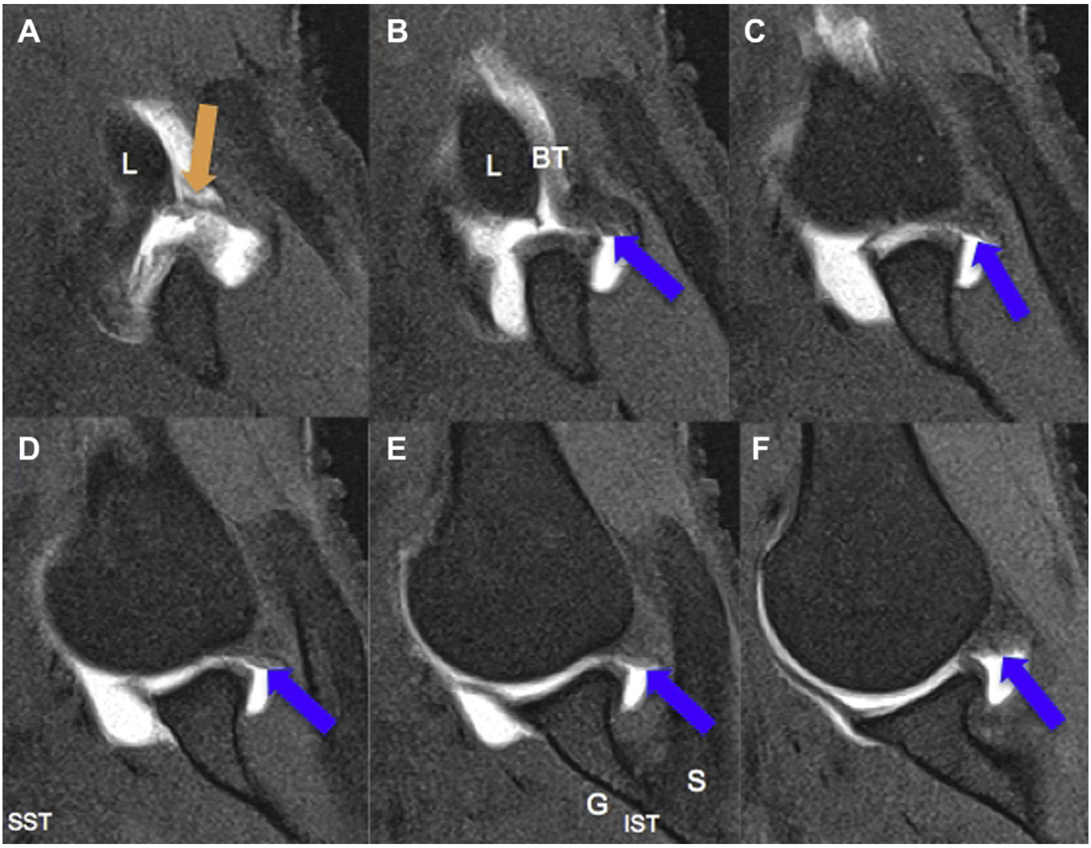

Fig. 8. (*A–F*) Rotator cable (*blue arrows*) and intact cuff. Consecutive ABER fat-suppressed T1-weighted images demonstrate the superior sling of the biceps pulley comprising the coracohumeral ligament fibers (*orange arrow*) providing the roof of the biceps tendon and in continuity with the cable along the undersurface of the supraspinatus (SST) and infraspinatus (IST) tendons. BT, biceps tendon; G, greater tuberosity; L, lesser tuberosity; P, coracoid process.

Sheah and colleagues[9] best identified the cable on non-ABER images in the setting of articular surface rotator cuff tears. Hence, they suggested that visualization of the cable on non-ABER images should prompt the radiologist to look for a partial-thickness tear of the rotator cuff. Towers and colleagues[18] measured the medial displacement of the cable in the setting of rotator cuff tearing and found an association between the position of the rotator cable relative to the greater tuberosity and the cross-sectional involvement of the tear at surgery. Oblique coronal fat-suppressed T2-weighted images were used to locate the image on which the articular surface of the cable was the farthest from the lateral margin of the greater tuberosity. Cable distance of less than 1.7 cm was associated with the absence of tears greater than 30% in cross section, and a cable distance of 3 cm was associated with the absence of tears less than 50%. The correlation coefficient between cable distance and cross section of the tear was 91%. Therefore, a cutoff

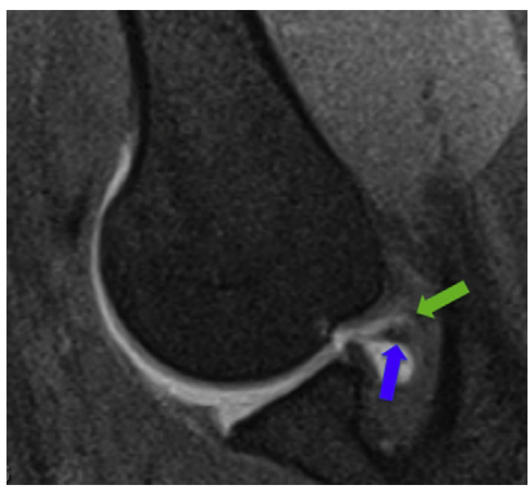

Fig. 9. Rotary cuff cable and articular surface supraspinatus tendon tear. ABER fat-suppressed T1-weighted image demonstrates the rotator cable (*blue arrow*) along the undersurface of torn, retracted supraspinatus tendon articular surface fibers (*green arrow*).

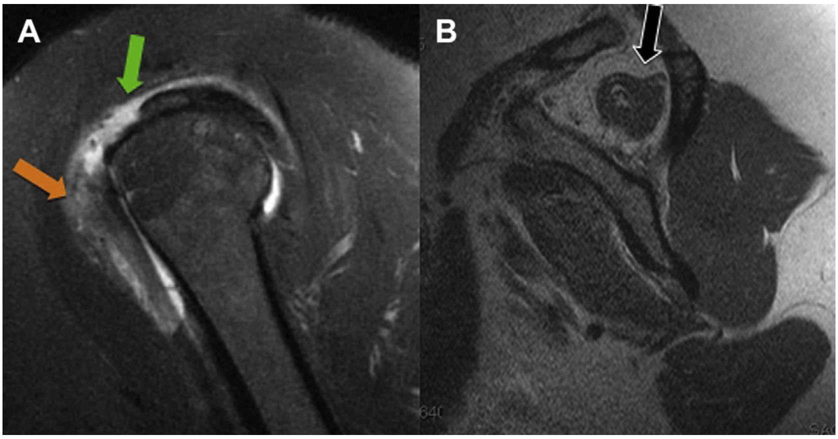

Fig. 10. Anterosuperior rotator cuff tear. (*A*) Oblique sagittal fat-suppressed T2-weighted image demonstrates a full-thickness tear of the anterior supraspinatus tendon fibers (*green arrow*) extending across the rotator interval into the superior subscapularis tendon fibers (*orange arrow*). (*B*) There is advanced fatty degeneration and retraction of the supraspinatus muscle (*black arrow*) on this sagittal oblique T1-weighted image.

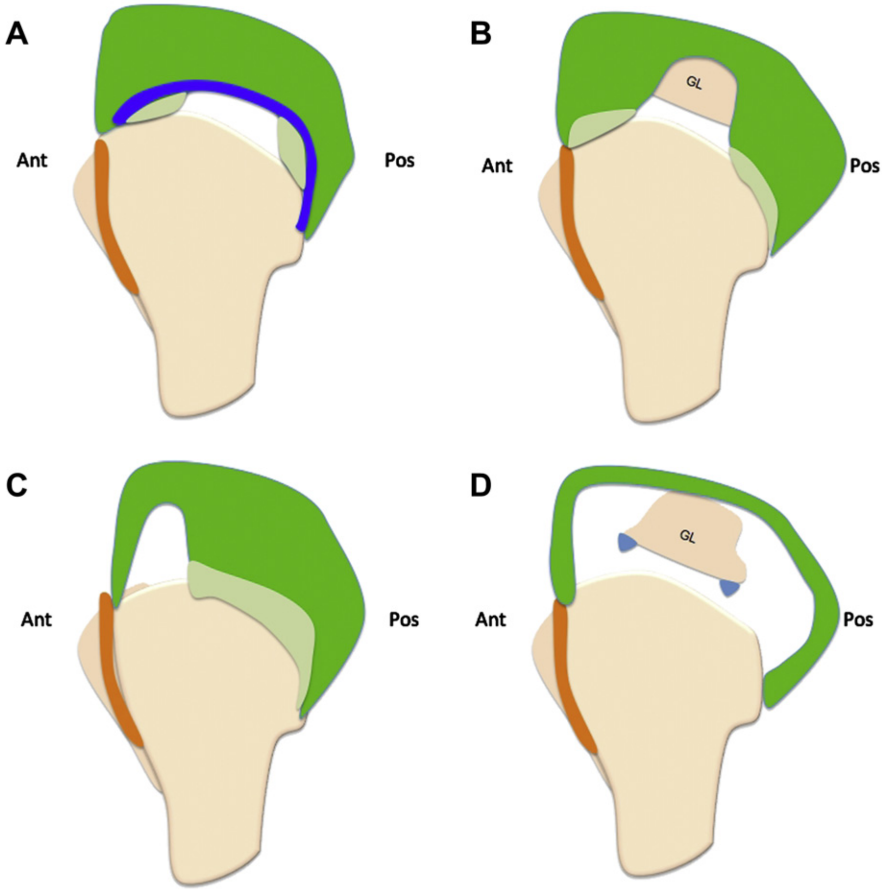

Fig. 11. (*A–D*) Rotator cuff tear shapes. (*A*) Crescent-shaped tear. (*B*) U-shaped tear. (*C*) L-shaped tear. (*D*) Massive tear. Rotator cuff, green; rotator cable, blue; rotator crescent, light green; biceps tendon, orange. GL, glenoid.

value of 1.7 cm in medial displacement of the cable was found to be most useful when differentiating between the small partial tears and the more extensive partial tears.

The association between tearing of the anterior cable attachment and altered biomechanics of the glenohumeral joint was reported by Su and colleagues.[19] Significant anterior and anterosuperior glenohumeral translation was seen in the setting of insertional tears involving the supraspinatus and superior half of the subscapularis tendons with loads of 40 and 50 N. No significant translation was found with isolated supraspinatus tendon tears. Based on the established anatomy of the cable, a tear that propagates from the supraspinatus tendon through the superior aspect of the subscapularis tendon has to involve the anterior attachment of the cable (**Fig. 10**). Even when not directly visualized in the images, the MR diagnosis of anterosuperior rotator cuff tears can thus suggest rotator cable compromise and associated altered glenohumeral joint mechanics (**Fig. 11**). An association between the visualization of the cable in the presence of a partial-thickness supraspinatus tendon tear and a negative Jobe test was noted by Macarini and colleagues.[10] This association suggested a possible biomechanical role for the cable in the setting of a partial-thickness supraspinatus tendon tear, although this finding was not statistically significant.

A study by Kim and colleagues[20] described the relationship between the size and location of a rotator cuff tear and fatty degeneration of the rotator cuff musculature. Their study demonstrated that the integrity of the anterior supraspinatus tendon was an important factor in the development of fatty degeneration of supraspinatus muscle. Specifically, the odds of fatty degeneration of supraspinatus muscle were increased when there was tearing of the anterior margin of the tendon. One of the investigators' hypotheses to explain this finding was based on the presence of the anterior insertion of the rotator cable into these anterior fibers. It was hypothesized that injury to the anterior insertion would weaken the cable, leading to its decreased functioning, resulting in rotator cuff instability and increased muscle retraction. This retraction would then lead to fatty degeneration of the rotator cuff musculature. Although indirect, these findings provide further support for the important biomechanical role of the cable (see **Fig. 11**).

The rotator cable may also play a role in the configuration of rotator cuff tears. As stated earlier, a rotator cuff tear can be modeled after a suspension bridge, with the free margin of the tear corresponding to the cable and the anterior and posterior attachments of the tear corresponding to the supports at each end of the cable's span. The rotator cable can limit the extension of a tear in both the anterior-posterior and medial-lateral planes.[2–5] The barrier-like effect of the cable can shape the extent of tearing, most commonly resulting in a crescent-type tear (see **Fig. 11**). Tears in a cable-deficient rotator cuff would not be limited in extent and could propagate in both the anterior-posterior and medial-lateral planes, which could result in variously shaped cuff tears, most commonly U-shaped, L-shaped, and massive contracted tears (see **Fig. 11**).

Crescent-shaped tears have an excellent medial to lateral mobility, regardless of the size, and can be repaired directly to bone with minimal tension (**Figs. 12–14**).[21] U-shaped tears extend much farther medially, with the apex of the tear adjacent to or medial to the superior glenoid rim (**Fig. 15**). In a study by Sallay and colleagues,[22] the U-shaped rotator cuff tear appeared to be the most common end result of the other types of rotator cuff tears. L-shaped tears are similar to U-shaped tears; however, in the L-shaped tear, one of the leaves is more mobile than the other leaf and can be more easily brought to the bone bed and to the other leaf (**Fig. 16**). L-shaped tears can extend anteriorly into or near the rotator interval (anterior L-shaped tear), or posteriorly into the posterior supraspinatus/anterior infraspinatus tendons (posterior L-shaped tear).[21] Recognizing a longitudinal type of tear (U-shaped, L-shaped) is critical because attempting to mobilize and repair the apex of the tear to a lateral bone bed will result in extreme

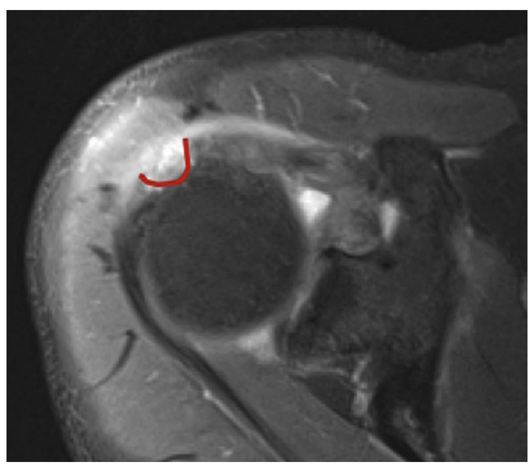

Fig. 12. Crescent-shaped tear, axial plane. Axial fat-suppressed proton-density image of the left shoulder demonstrates a crescent-shaped tear (*red line*) with narrow transverse and narrow longitudinal components located at the junction of the supraspinatus and the infraspinatus tendons.

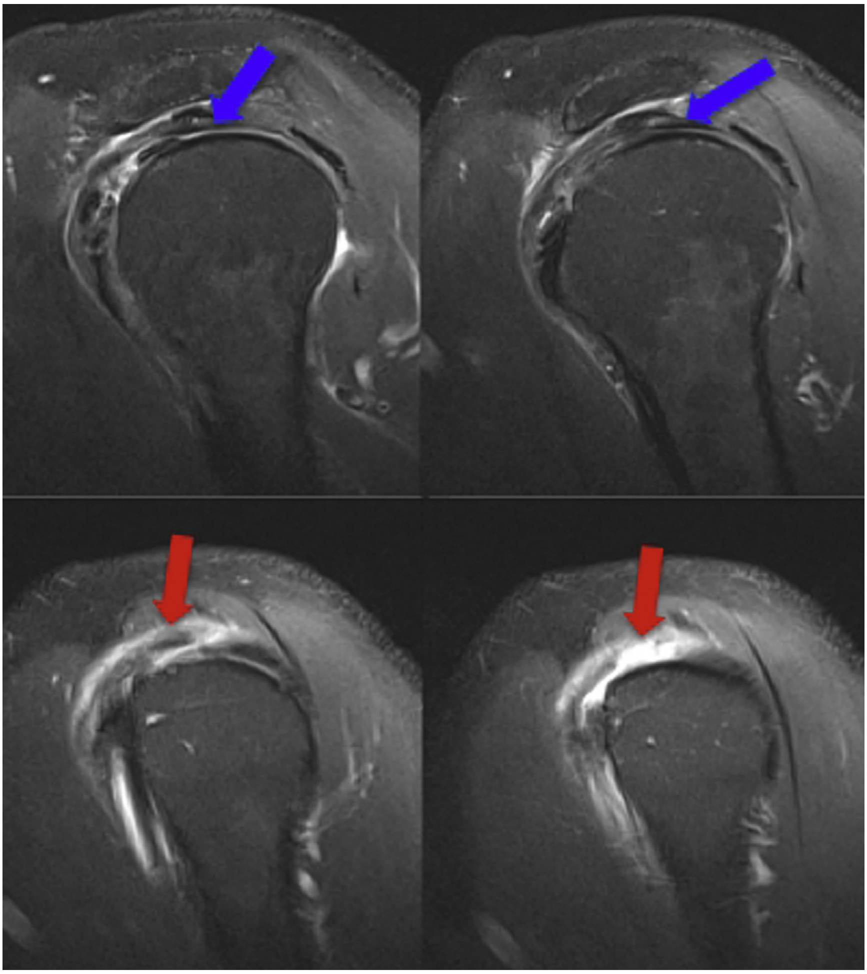

Fig. 13. Crescent-shaped tear, sagittal oblique plane. Multiple consecutive sagittal oblique fat-suppressed T2-weighted images of the right shoulder in the same patient as in Fig. 12 demonstrates a crescent-shaped full-thickness tear at the junction of the supraspinatus and infraspinatus tendons (*red arrows*). The coracohumeral ligament arises from the coracoid process and extends along the undersurface of the supraspinatus and infraspinatus tendons as the rotator cable (*blue arrows*).

tensile forces in the repaired cuff margin, leading to tensile overload and subsequent tendon failure. Therefore, tears with a deep longitudinal component respond best to repair techniques using margin convergence. Massive, contracted, rotator cuff tears demonstrate no mobility from medial to lateral or from anterior to posterior, and therefore cannot be repaired directly to bone or side to side with margin convergence (Fig. 17).[21]

CLINICAL SIGNIFICANCE

Arthroscopically, the cable appears as a thickening at the distal margin of the undersurface of the rotator cuff (Fig. 18). It can be routinely seen in the arthroscopy of the intact rotator cuff.[3] In cases of massive rotator cuff tears, the rindlike rotator cable can be easily identified after debridement of the thin crescent tissue (Fig. 19). The presence of an intact rotator cable may change the clinical approach to a massive tear of the rotator cuff, particularly in elderly patients. In this context, the ability to identify the rotator cable with MR imaging can provide a great benefit to the surgeon not only in evaluating the patient as a candidate for operative management but also in planning the procedure to be performed.

The concept of a functional rotator cuff tear describes rotator cuffs that are anatomically deficient, yet biomechanically sound because of the action of the rotator cable in transmitting the forces between the anterior and posterior margins of the tear, thereby allowing for force coupling between internal and external rotators of the

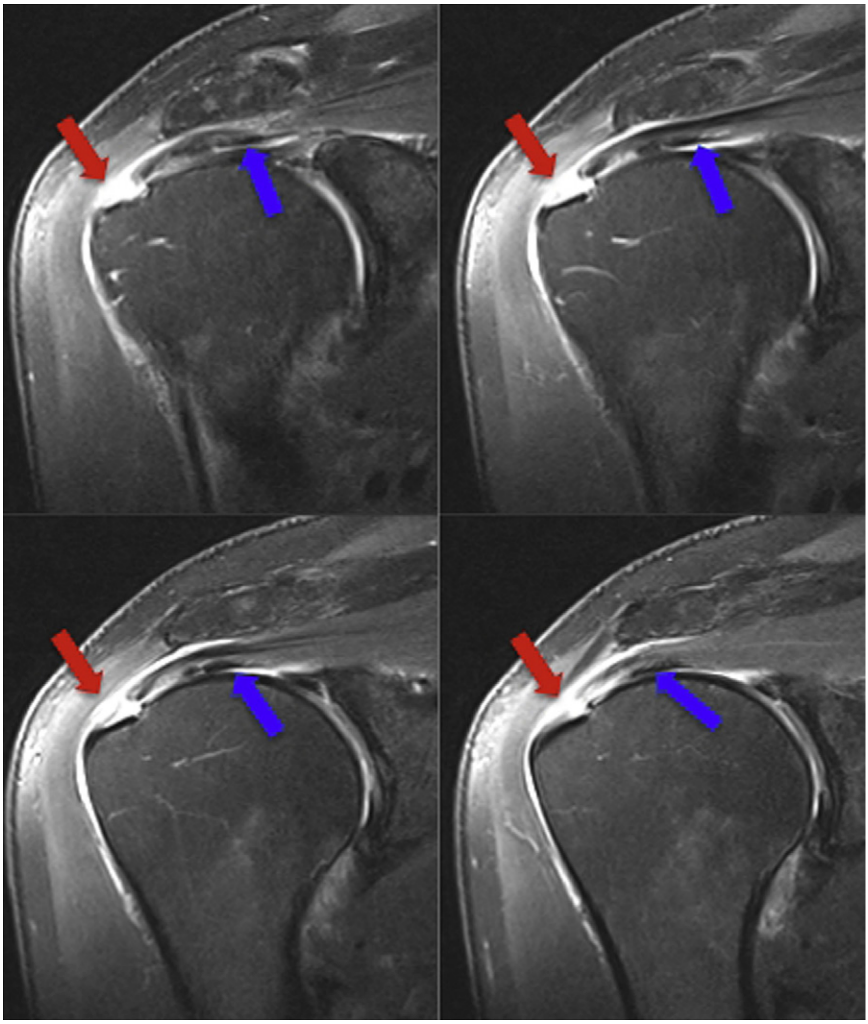

Fig. 14. Crescent-shaped tear, coronal oblique plane. Multiple consecutive coronal oblique fat-suppressed T2-weighted images of the right shoulder from the same patient as in Figs. 12 and 13 demonstrate a crescent-shaped full-thickness tear at the junction of the supraspinatus and infraspinatus tendons (*red arrows*). The rotator cable courses along the undersurface of the supraspinatus and infraspinatus tendons (*blue arrows*).

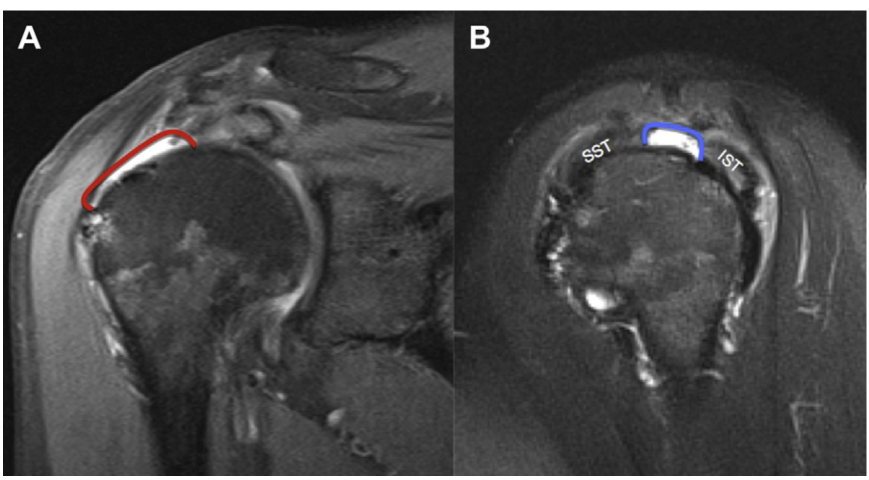

Fig. 15. (*A*, *B*) U-shaped tear. A fluid-filled cuff defect is seen at the junction of the supraspinatus and infraspinatus tendons on coronal (*A*) and sagittal (*B*) oblique fat-suppressed T2-weighted images of the right shoulder. The U-shape is defined by a long longitudinal component (*red line*) compared with a narrow transverse component (*blue line*), and is typically found at the junctional zone of the supraspinatus and infraspinatus tendons.

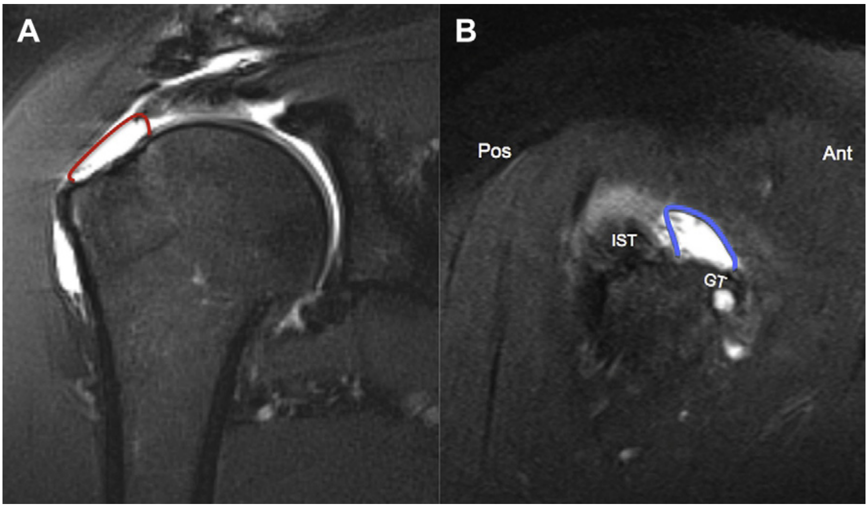

Fig. 16. (*A*, *B*) Anterior L-shaped tear. An anterior L-shaped tear is seen within the supraspinatus tendon on coronal (*A*) and sagittal (*B*) oblique fat-suppressed T2-weighted images of the right shoulder. The anterior L-shape is defined by a long longitudinal component (*red line*) compared with a narrow transverse component (*blue line*) as well as the location within the anterior half of the rotator cuff insertion onto the greater tuberosity (GT). IST, infraspinatus tendon.

shoulder.[23,24] Although complete surgical repair of rotator cuff tears should be the goal, certain massive tears cannot be adequately repaired. In these cases, Burkhart and colleagues[24] have shown that partial repair can lead to acceptable results, provided the force-couple and the rotator cable are restored. In a study of 14 patients with an average follow-up of 21 months, the authors achieved an average postoperative University of California, Los Angeles (UCLA) score of 27.6, with 8 good or excellent results (compared with an average preoperative UCLA score of 9.8). In another study, Burkhart[25] showed that simple arthroscopic debridement and decompression could lead to good results in patients with painful, but functional rotator cuff tears.

The clinical evidence for a partial repair is further supported by a biomechanical study by Halder and colleagues.[26] In their study, tears involving one-third to two-thirds of the supraspinatus tendon resulted in minimal decreases in force transmission. A significant decrease in force transmission through the rotator cuff occurred only after detachment of the entire supraspinatus tendon,

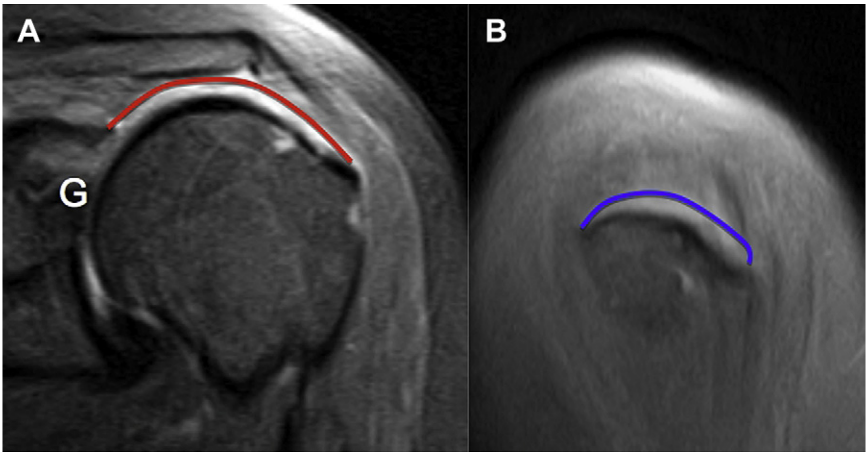

Fig. 17. Massive tear. Coronal (*A*) and sagittal (*B*) fat-suppressed T2-weighted images of the left shoulder demonstrate a massive, retracted cuff tear with long longitudinal (*red line*) and wide transverse components (*blue line*). The tendon fibers are retracted to the level of the glenoid (G), and the greater tuberosity facets are bare.

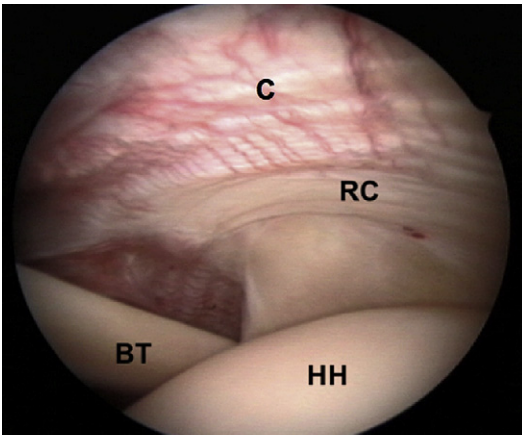

Fig. 18. Rotator cable on arthroscopy. Arthroscopic view of the rotator cable (RC) coursing along the undersurface of the rotator cuff (C). BT, biceps tendon; HH, humeral head. (*Courtesy of* Brian J. Cole, MD, MBA.)

thereby affecting the rotator cable. Furthermore, an attempt to restore the rotator cable with a side-to-side repair after the complete excision of the supraspinatus tendon restored force transmission to 90% of the original value.

The identification of the rotator cable on MR imaging can provide valuable information to the surgeon. In the case of an elderly patient with a functional painful rotator cuff tear, the presence of an intact rotator cable suggests that the patient may benefit from an arthroscopic debridement and decompression. Conversely, in patients with massive rotator cuff tears and a disrupted rotator cable, consideration should be given to the restoration of the rotator cable via a partial repair.

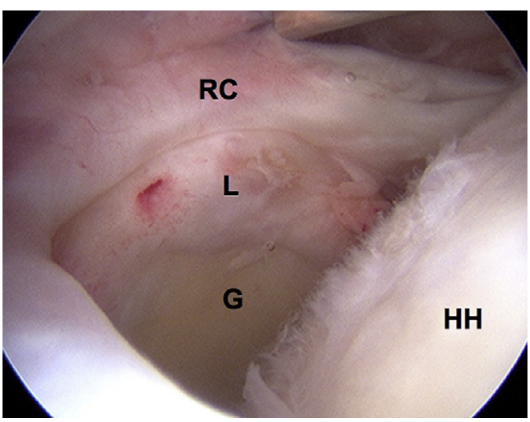

Fig. 19. Rotator cable in the setting of a massive cuff tear on arthroscopy. The rotator cable (RC) is retracted to the level of the superior glenoid rim in this 57-year-old woman with a massive rotator cuff tear who underwent arthroscopic debridement. G, glenoid; L, labrum; HH, humeral head.

SUMMARY

The rotator cable is an extension of the coracohumeral ligament coursing along the undersurface of the supraspinatus and infraspinatus tendons. The rotator cable is thought to play a role in the biomechanical function of the intact and torn rotator cuff, and possibly in the configuration of rotator cuff tears. It can be seen on all the imaging planes used for conventional MR imaging of the shoulder. Clinically, the integrity of the rotator cable can play a role in treatment selection for patients with a rotator cuff tear.

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